DESIGN AND ANALYSIS OF SPUR GEAR USING ANSYS

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Abstract: In the present work, Static analysis is performed to determine the Factor of Safety and Von-mises stresses. The analysis is done by considering different materials for gears like Structural Steel, AlBeMet – 162, AISI 1080 Steel, Carbon epoxy fiber, and results are compared. The aim is to replace the cast iron spur gear or steel spur gear with these composites. These composites have better strength, low weight, and damping characteristics, and better performance which often exhibits less wear rate.

1.INTRODUCTION

A Gear is a machine element is used to transmit motion and power between rotating shafts using progressive engagements of projections. They have a wide variety of applications which varies from watches to very large mechanical units like lifting devices and automotive. Engineering components made of composite materials find increasing applications ranging from spacecraft to small instruments. These Gears may predominate as the most effective means of transmitting power in future machines due to their high degree of reliability and compactness. Husaini and DM Dawud (1) investigated the cause of the spur gear fracture through numerical studies. Pradeep Kumar Singh, ManwendraGautam, Gangasagar, Shyam Bihari Lal (2) investigated to minimized the failures in gears by analysis of the problem during the design stage and creating a proper tooth surface profile by using Ansys workbench software.

Sushovan Ghosh, Rohit Ghosh, Bhuwaneshwar Patel, Tanuj Srivastava, and Dr. Ravindra Nath Barman (3) reviewed the static analysis of the spur gear in the existing automobile gearbox considering its material geometrical parameters and the manufacturing processes. Shanmuga sundaram Sankar, Masanamuthu Sundar Raj, Muthusamy Nataraj (4) examined the tooth failure in spur gears. Corrective measures are taken to avoid tooth damage by introducing profile modification in the root fillet. Mrs. Shinde S.P., Mr. Nikam A.A, Mr. Mulla T.S.(5) reviewed the characteristics of spur gears in a gearbox that will be studied using the linear Finite Element Method. In the Review Paper On Analysis Of Spur Gear,V. A. Gavali, C. P. Satav (6)discussed that gears while transmitting the power generates high stresses at the mating positions over the teeth as they amend the rate of rotation of the machine shaft. In the Project Report, Maximum Torque of combination threats for spur gear based on AGMA and JGMA Standard by WU JIA HANG (7) investigation of the transformation curve of gearing safety is discussed.

Ms. Nilesh U. Patil, Mr. Sunil P. Chaphalkar, Mr. Gajanan L. Chaudhari (8) reviewed the Analysis of Spur Gear by using Different Materials. Jillepalli Naresh Babu, (9)discussed the dynamic stress analysis mesh gear using Ansys software. B. Siva kumar, I. Joe Michael discussed the Experimental results from testing the spur gear under a moment and the Analysis has been carried out by optimizing the material such as carbon fiber high modulus. Prathamesh Surnis, Dr. Pravin Kulkarni (11)gives a detailed and comprehensive procedure of material to be selected for a Spur Gear Design. K Senthilna than et al (12) designed and analyzed of gear testing kit, for testing the load generation developed on the gear tooth through the brake drum.

Shanavas S. (13) discussed replacing the cast iron spur gear with carbon fiber epoxy composite spur gear. For that, analytical and finite element methods are applied for determining bending stresses and contact stresses of the gear tooth. Nair Ajit V (14) discussed the failures in gear teeth when the load is increased beyond a limit. Putti Srinivasa Rao, (15) discussed the bending stress over the lower addendum of the spur gear, shear, and contact stresses by using the software tools like pro-e and

ANSYS.

2. PROBLEM STATEMENT & METHODOLOGY:

The objective of the present work is to analyze the spur gear made up of different types of materials such as Structural steel, AlBeMet – 162, AISI 1080 Steel, and Carbon fiber epoxy. First, the Spur Gear is designed in Dassault Systems and assembled in CATIA V5, and analysis is conducted on ANSYS 19.2. The fixed support and torque are applied to the Spur Gear. Static analysis is performed to obtain the Maximum Principal Stress, Equivalent Von-Misses Stress, and Total Deformation of Spur Gear subjected to boundary condition, and then Torque is applied to the Spur Gear.The static analysis is performed by applying a Torque of 225 N-m to the Frictionless support of the spur gear assembly for this Total Deformation and Equivalent Von-Misses Stress is obtained. The same procedure is conducted for different materials like Structural Steel and AlBeMet – 162, AISI 1080 Steel, and Carbon fiber epoxy. The results of Equivalent Stress Maximum Principal Stress and Total Deformation are compared.

2.1 Geometry:

The dimensions of a spur gear are Pitch circle diameter (p.c.d) = 180mm,Number of teeth = 18, Outside circle diameter = 200mm, Circular pitch = 31.4mm, Dedendum circle diameter = 156.86mm, Dedendum = 11.57mm, Addendum = 10mm, Module = 10mm, Fillet radius = 3.9mm, thickness of the tooth = 15.71mm, Face width (b) = 54mm

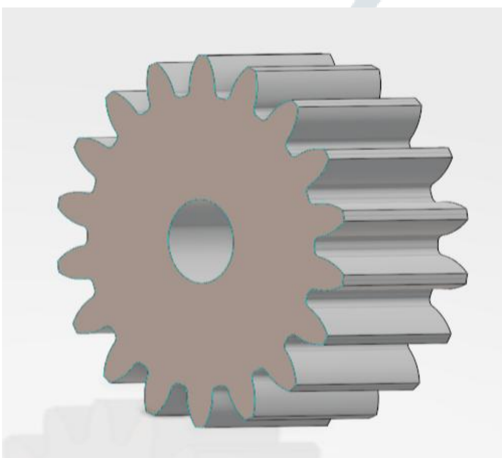

Fig 1: Design of Spur Gear

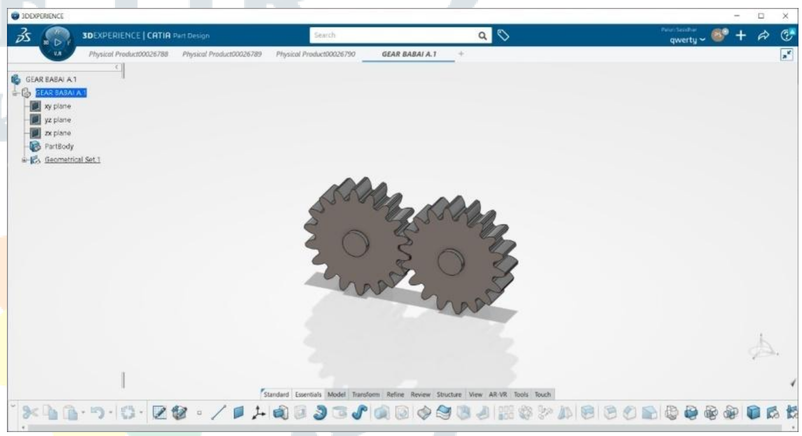

Fig 2: Assembly of Spur gear

2.2 Design Calculations

TORQUE (T) = 13.8kg-m@2500rpm

POWER (P) = 2 x 3.14 x 2500 x T/60

P = 2 x 3.14 x 2500 x 138/60;

P = 36128

Watt Power (P) = 36.128 K Watt

Torque (T) = F x (d/2)

Where,

F-load,

d- Pitch circle diameter (z x m=180mm)

T= F x (d/2)

F = T/ (d/2)

F = 138000/90 Load

(F) = 1533.33N

Tangential load, F =b x y x P_c x σ_b

P_c = 3.14 x module

P_c = 31.4mm

Y= Lewis form factor=0.134mm

b = face width = 54mm

Table 1: GEAR TOOTH PARAMETERS

Terms	Symbols	Terms	Symbols
Module	m	Tooth Thickness	s
Pressure Angle	A	Reference Diameter	d
Number of Teeth	Z	Tip Diameter	d_a
Pitch	P	Root Diameter	d_f
Tooth Depth	h	Center Distance	a
Addendum	h_a	Backlash	j
Dedendum	h_f	Tip and Root Clearance	c

- Pitch circle diameter (P.C.D) = z x m = 18 x 10 = 180mm
- Base circle diameter (D_b) = D cos α = 180 x cos20 = 169.145mm
- Outside circle diameter = (z+2) x m= (18+2) x 10 = 200mm
- Clearance = circular pitch/20 = 31.4/20 = 1.57mm
- Dedendum = Addendum + Clearance = 10+1.57 = 11.57mm
- Module = D/Z = 180/18 = 10mm
- Dedendum circle diameter = P.C.D – (2 x dedendum) = 80 - (2 x 11.57) = 156.86mm
- Fillet radius = Circular pitch/8 = 31.4/8 = 3.9mm
- Pitch circle diameter (Pc) = m x z = 10 x 18 = 180mm
- Hole depth = 2.25 x m = 2.25 x 10 = 22.5mm
- Thickness of the tooth = 1.571 x 10 = 15.71mm
- Face width (b) = 0.3 x 180= 54mm
- Center distance between two gears = 180mm
- Diametral pitch = Number of teeth/P.C.D= 18/180= 0.1mm

Whereas,

z = Number of teeth,

m = Module.

2.3 Material properties:

The material properties of Structural steel, AlBeMet– 162, AISI 1080 Steel, and Carbon fiber epoxy are as given below.

Table 2: Mechanical properties

Parameter \ Material	Structural steel	AlBeMet– 162	AISI 1080 Steel	Carbon fiber epoxy
Density (g/m^-3)	7080	2070	7800	1600
Young's Modulus(Pa)	2E+11	1.79E+11	2E+11	1e+10
Poisson's ratio	0.3	0.17	0.285	0.3
Bulk modulus	1.66667E+11	9.0404E+10	1.5504E+11	8.3333e+09
Shear modulus	7.6923E+10	7.6496E+10	7.7821E+10	3.8462e+08
Tensile yield strength (Pa)	2.5E+08	1.93E+08	9.05E+08	1.5e+09
Tensile ultimate strength (Pa)	4.6E+08	2.85E+08	1.035E+09	3.5e+09

2.4Chemical Composition of Materials:

The chemical composition of Structural steel, AlBeMet–162,AISI 1080 Steel, and Carbon fiber epoxy is as given below

Table 3: Chemical composition of the Structural steel

Fe	C	Mn	Si	S
98%	0.10%	1.0%	0.15%	0.005%

Table 4: Chemical composition of the AlBeMet - 162

Al	Be
0.38%	0.62%

Table 5:Chemical composition of the AISI 1080 Steel

C	Fe	Mn	P	Sn
0.88%	98.6%	0.9%	0.04%	0.05%

Table 6: Chemical composition of the Carbon fiber epoxy

Carbon	Petroleum Pitch
90%	10%

2.5 Loading &Boundary conditions:

The following types of loads and boundary conditions are applied for the prediction of the response of the structure in the static analysis. The driving Gear is fixed and a Torque of225 N-m is applied to the driven Gear.

2.6 RESULTS AND DISCUSSION

2.6.1 Fem Analysis of spur gear:

The spur gear is made up of steel material. The spur gear is designed as per dimensions and loads and boundary conditions are applied. The static analysis of carried out and the following results are obtained from static analysis.

Table 7: Maximum Principal Stress & Maximum Principal Elastic Strain

Spur gear	Maximum Principal Stress		Maximum Principal Elastic Strain	
	Max (Pa)	Min (Pa)	Max(m/m)	Min(m/m)
Structural Steel	9.618e+006	-8.8543e+005	5.7898e-005	-7.6877e-008
AlBeMet– 162	4.0977e+006	-4.7195e+005	2.011e-005	-6.7591e-008
AISI 1080 Steel	3.2938e+006	-4.5078e+005	1.5379e-005	0
Carbon fiber epoxy	2.7971e+007	-2.8538e+006	4.6102e-004	-3.3786e-007

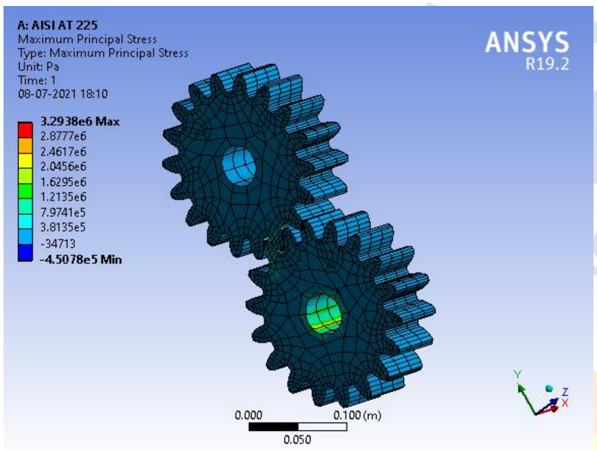

Fig 3 Max Principal Stress of Structural Steel

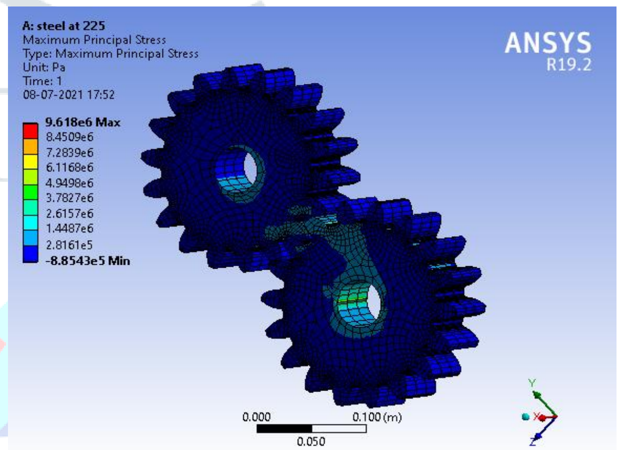

Fig 4 Max Principal Stress of AlBeMet - 162

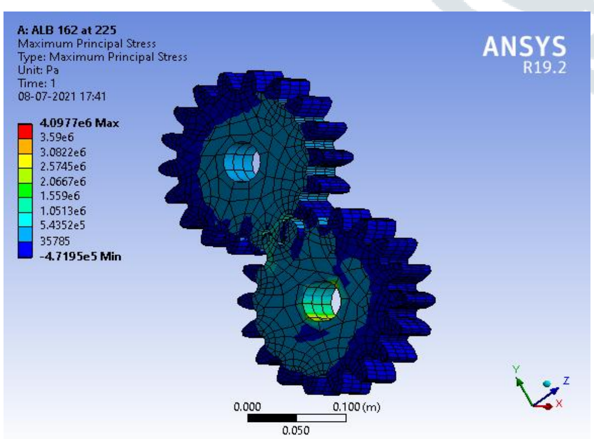

Fig 5 Max Principal Stress of AISI 1080 Steel

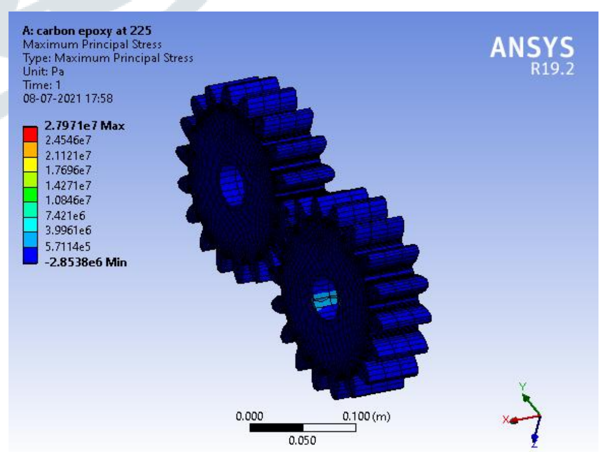

Fig 6 Maximum Principal Stress of Carbon fiber epoxy

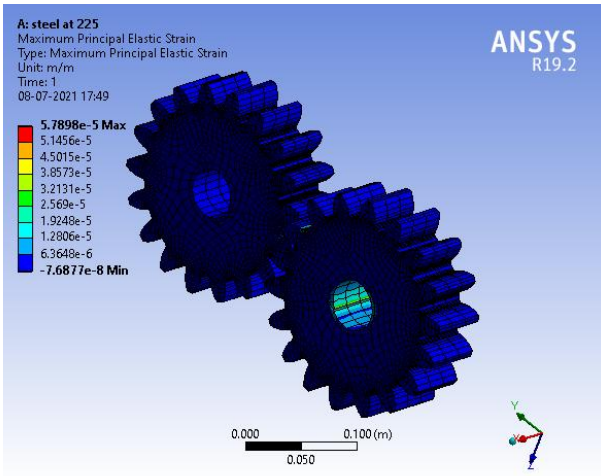

Fig 7 Maximum Principal Elastic Strain of Structural Steel

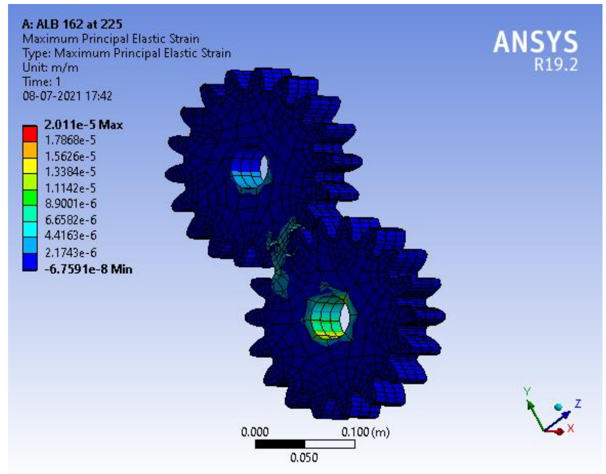

Fig 8 Maximum Principal Elastic Strain of AlBeMet - 162

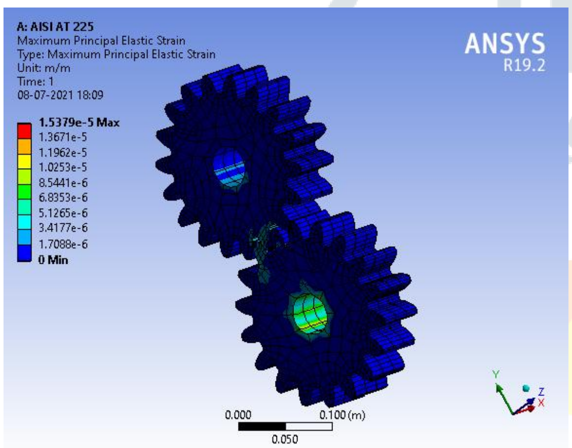

Fig 9 Maximum Principal Elastic Strain of AISI 1080 Steel

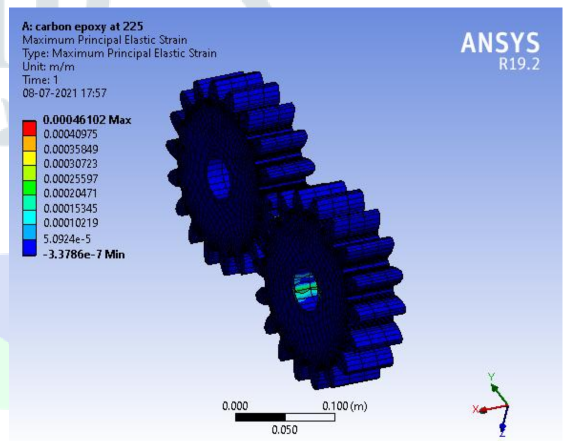

Fig 10 Maximum Principal Elastic Strain of Carbon fiber epoxy

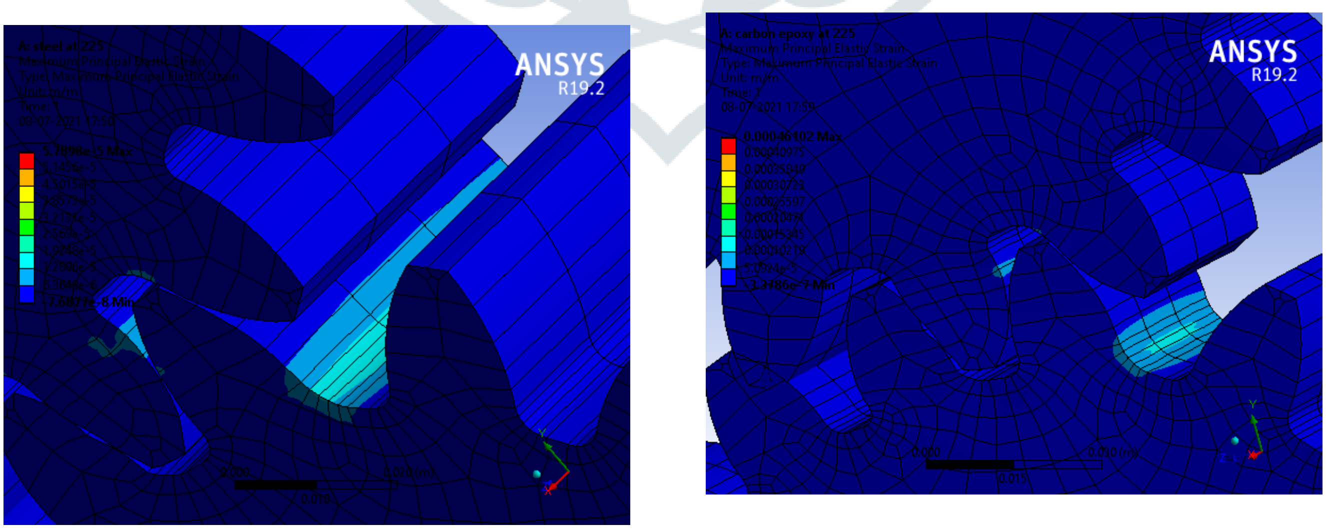

Figure 11 Maximum Principal Elastic Strain of Structural Steel and Carbon Epoxy

Table 8 Equivalent Stress (Von-mises) & Equivalent Elastic Strain

Spur gear	Equivalent Stress (Von-mises)		Equivalent Elastic Strain	
	Max (PA)	Min(PA)	Max(m/m)	Min(m/m)
Structural Steel	1.4513e+007	3.0223e-004	1.0319e-004	1.7702e-014
AlBeMet - 162	4.1461e+006	0	3.9259e-005	0
AISI 1080 Steel	5.0459e+006	0	2.5847e-005	0
Carbon fiber epoxy	3.9125e+007	1.0428e-003	1.2781e-003	2.623e-014

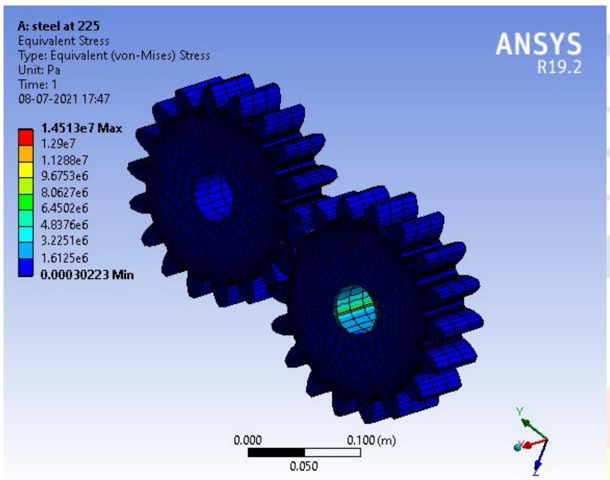

Fig 12 Equivalent Stress of Structural Steel

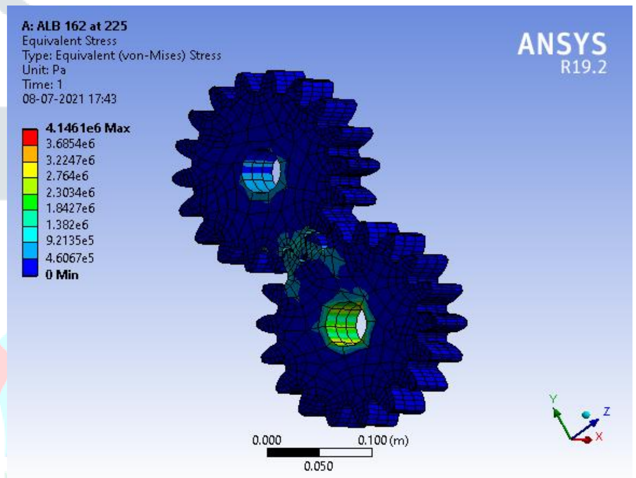

Fig 13 Equivalent Stress of AlBeMet - 162

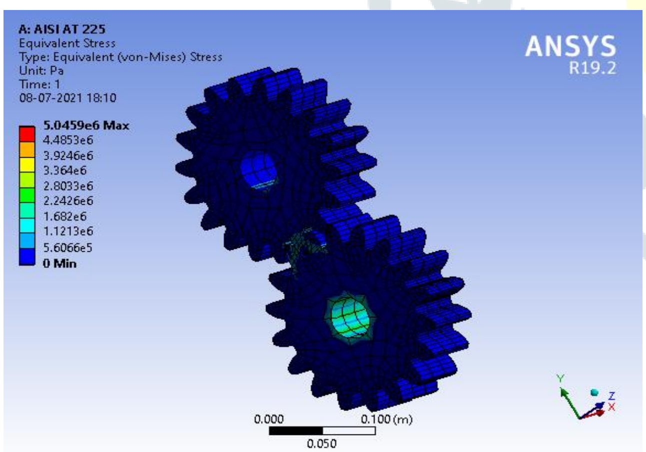

Fig 14Equivalent Stress of AISI 1080 Steel

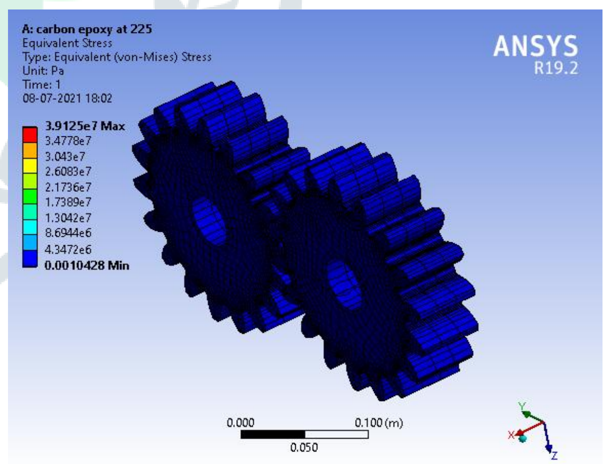

Fig 15Equivalent Stress of Carbon fiber epoxy

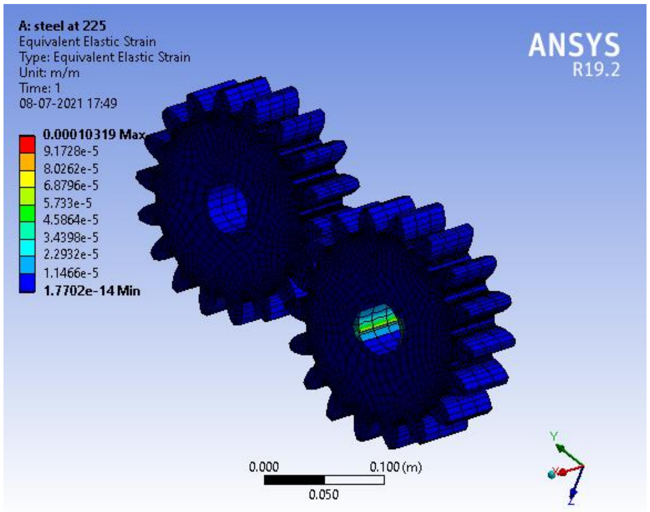

Fig 16 Equivalent Strain of Structural Steel

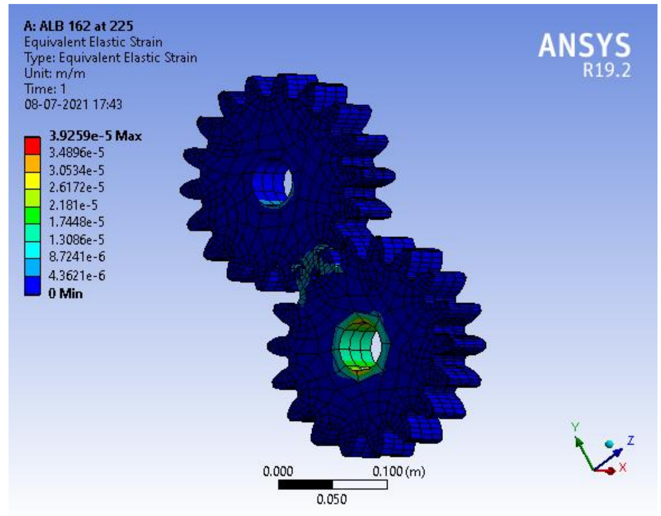

Fig 17 Equivalent Strain of AlBeMet - 162

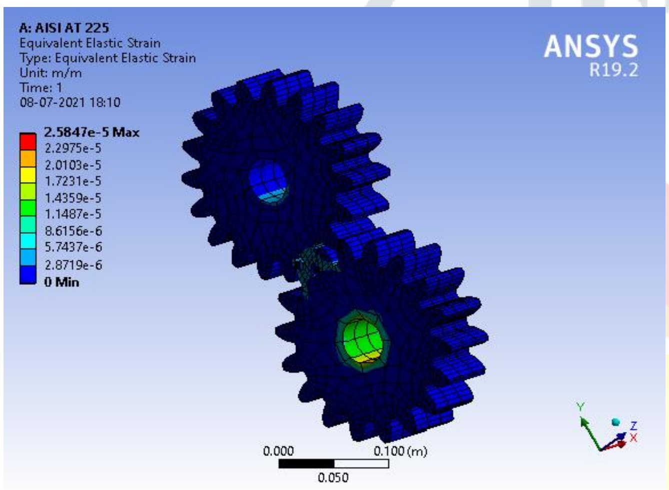

Fig 18 Equivalent Strain of AISI 1080 Steel

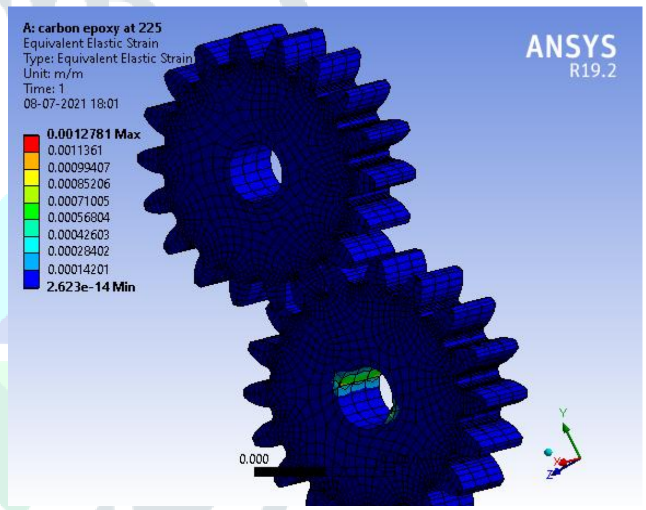

Fig 19 Equivalent Strain of Carbon fiber epoxy

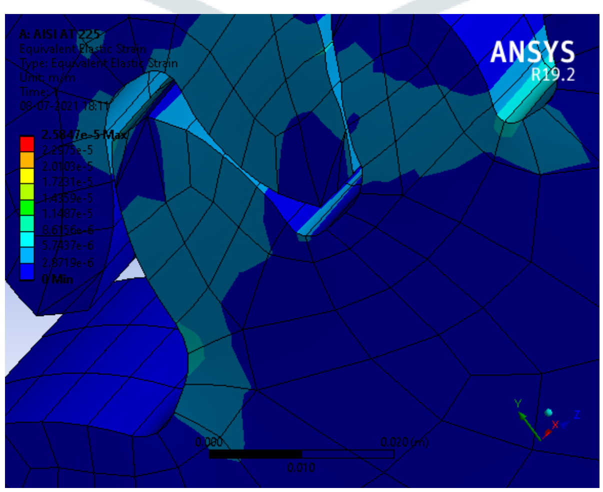

Fig 20 Equivalent Strain of AISI 1080 Steel

Table 9 Total deformation& Factor of safety

Spur gear	Total deformation		Factor of safety
	Max(m)	Min(m)	
Structural Steel	1.0284e-006	0	15
AlBeMet - 162	9.3608e-007	0	15
AISI 1080 Steel	6.5168e-007	0	15
Carbon fiber epoxy	6.7171e-006	0	6.3898

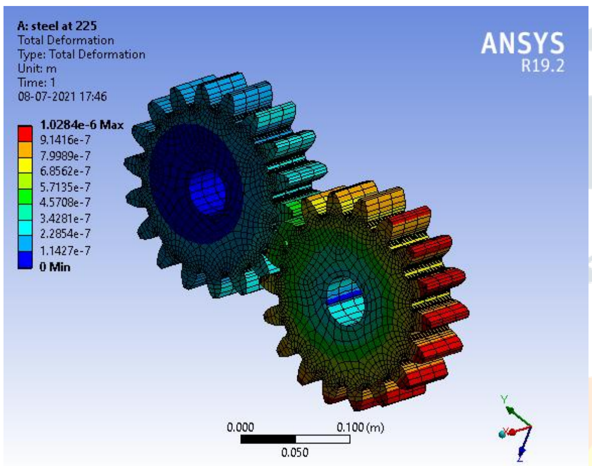

Fig 21Total deformations of Structural Steel

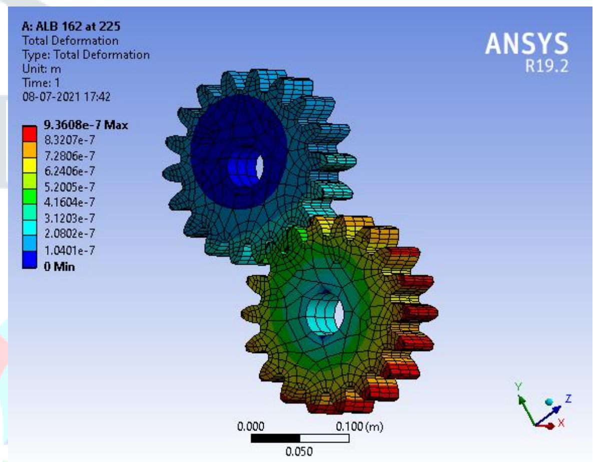

Fig 22 Total deformations of AlBeMet - 162

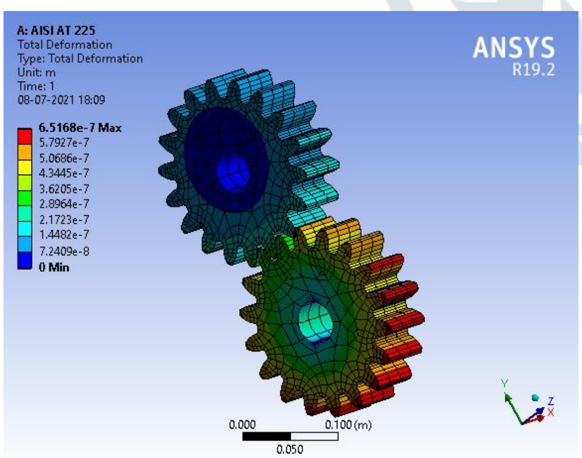

Fig 23 Total deformations of AISI 1080 Steel

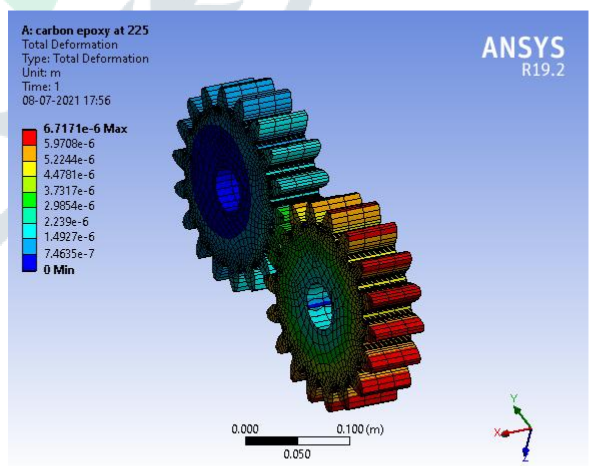

Fig 24 Total deformations of Carbon Fiber Epoxy

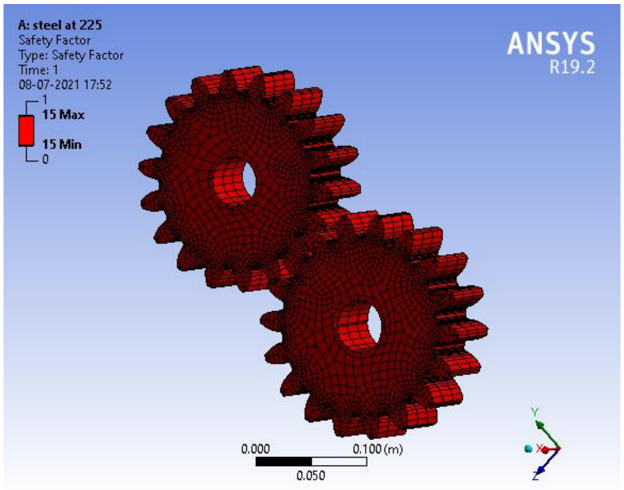

Fig25 The safety factor of Structural Steel

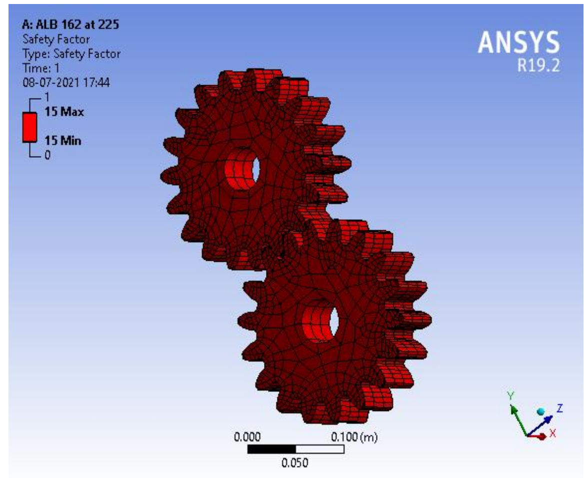

Fig 26 The safety factor of AlBeMet - 16

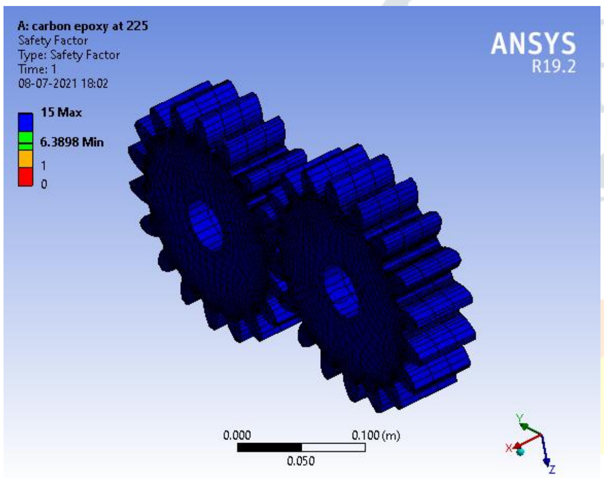

Fig 17 The safety factor of AISI 1080 Steel

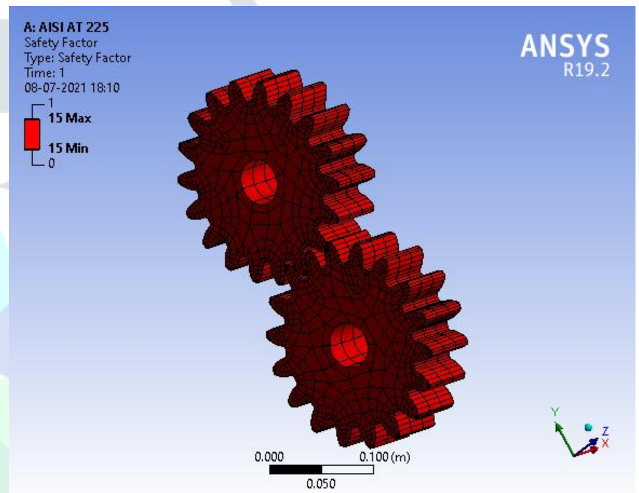

Fig 28 The safety factor of Carbon Fibre Epoxy

5.1 Conclusion:

In the present work, the analysis of spur gear made up of structural steel, ALBMet 162, AISI 1080 Steel, Carbone epoxy is examined in the application of gearbox which is used in automobile vehicles through Ansys.

- It was found that AlBeMet – 162,AISI 1080 Steel, and Carbon fiber epoxy has less stress-induced, strain and deformation when compared with structural steel and gray cast iron.
- The deformation and weight of the spur gears of these composite materials are less as compared to the structural steel.
- The factor of safety remains mostly the same for structural steel and composite materials.
- It was found that Carbone epoxy has got good resistance characteristics as compared to other materials.
- So from these analysis results, we may conclude that the stress-induced and deformation of these composite materials is less as compared to the steel spur gear.
- In Static analysis, carbon epoxy materials have good vibration resistance comparing to other materials.
- This study will help to understand more the behavior of the spur gear and gives information for the manufacturer to improve the strength of the spur gear. It can help to reduce the cost and time required for the research and development of new products.

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